Restoration of a Lost Symmetry

Mass Reduction of the η' Mesons in 10^{-22} Sec

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A particle called η' meson is found to reduce its mass in less than 10^{-22} second in high energy heavy ion collisions at RHIC. Apparently this is the fastest mass reduction ever observed. This indicates the restoration of a lost symmetry of strong interactions in a hot and dense, hadronic matter.

The η and the η' mesons are similar to a pair of identical twins – their quark content is identical. Under usual circumstances, however, the $\eta'(958)$ is nearly twice as heavy as its partner, the $\eta(548)$ meson. High energy heavy ion collisions at Brookhaven National Laboratory's RHIC accelerator generate a hot soup of quark gluon plasma (sQGP) which rehadronizes at temperatures of about 2 Terakelvin, and produces mesons like η and η' in a fleetingly short time of about 10^{-22} sec.

Recently, in a paper that appeared in the Physical Review Letters, we reported on an indirect observation of a significant, at least 200 MeV mass reduction of the η' mesons [1] in the hot and dense, hadronic medium. Such a medium is formed after the quarks and gluons of sQGP are reconfined into mesons and baryons in a process called hadronization. As long as the η' dwells in such a hot and dense, hadronic medium, the huge mass difference of 410 MeV between the η and the η' mesons disappears within the errors of the analysis, which is based on a combined dataset of the STAR and PHENIX Collaborations. This is just like what might happen in the blink of an eye if the overweight partner of a set of identical twins suddenly lost its extra weight and became the pre-calculated, ideal weight and shape of the slimmer twin.

Such a mass reduction might indicate a restoration of an important symmetry of strong interactions, the so-called $U_A(1)$ symmetry, and the return of a previously lost, "prodigal" Goldston boson, the in-medium modified η'. Our results indicate that this $U_A(1)$ symmetry is apparently restored in a hot and dense, hadronic matter [1]. This symmetry restoration happens at temperatures that are below the temperature range of sQGP formation, in agreement with theoretical predictions based on quark model calculations [2] and discretized (lattice) quantum chromodynamics [3].

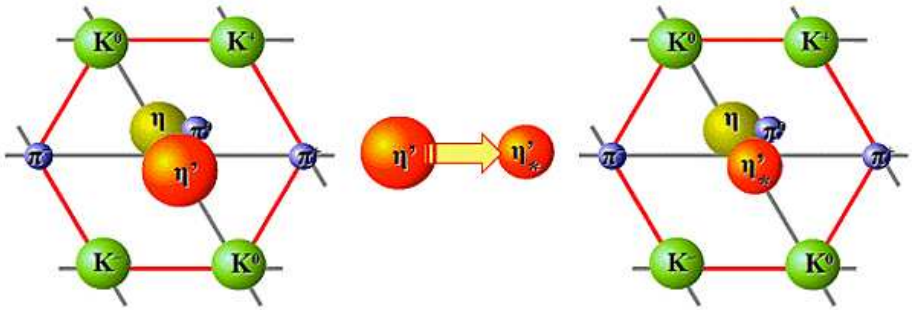

Figure 1: The 9 pseudoscalar mesons formed by u, d and s quarks are represented as pellets, with sizes proportional to their masses. The left panel indicates a usual situation, corresponding to masses measured in elementary particle induced reactions (Particle Data Group values). The medium plot indicates a mass reduction of the η' mesons in hot and dense hadronic matter, created in $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions at the Relativistic Heavy Ion Collider, Brookhaven National Laboratory, USA. The right panel indicates the restoration of a symmetry between the η and the η' mesons in hot and dense hadronic matter.

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